Chapter 9:

WAN Technology ad Protocols

Switching Networks

- **Switching nodes** - provide a switching facility that move data between nodes
- **Stations** – devices attached to the network
- **Nodes** – switching devices that provide communication
- **Communications network –** collection of nodes
- **Switched communication network** – data entering the network from a station are routed to the destination by being switched from node to node

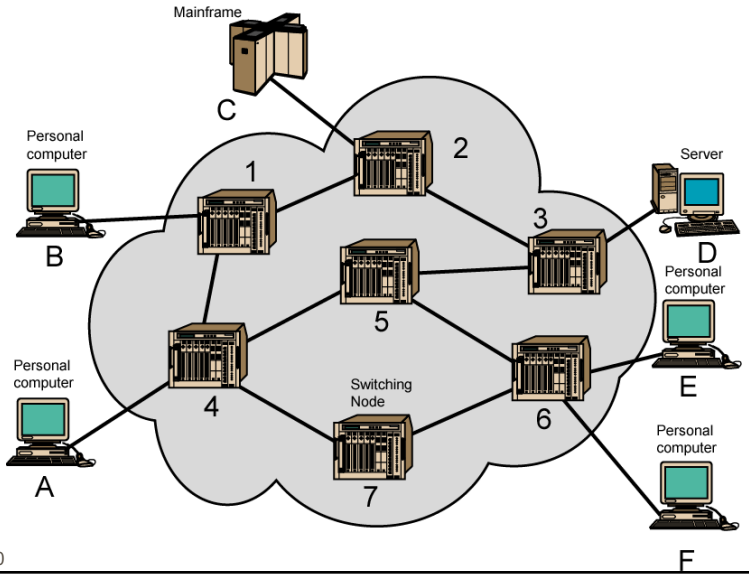
Switching Networks

- Long distance transmission is typically done over a network of switched nodes
- Nodes not concerned with content of data
- End devices are stations
  - —Computer, terminal, phone, etc.
- A collection of nodes and connections is a communications network
- Data is routed by being switched from node to node

Nodes

- Nodes may connect to other nodes only, or to stations and other nodes
- Node to node links usually multiplexed
- Network is usually partially connected
  - —Some redundant connections are desirable for reliability
- Two different switching technologies
  - —Circuit switching
  - —Packet switching

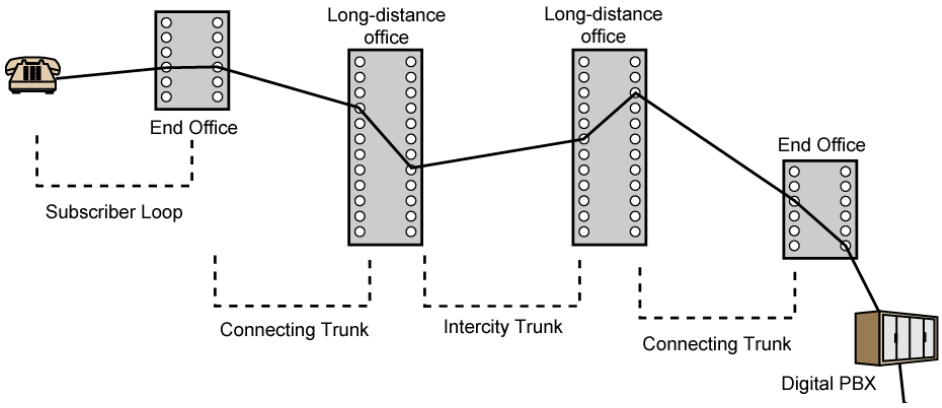
Simple Switched Network



Circuit Switching

- Dedicated communication path between two stations
- Three phases
  - —Establish
  - —Transfer
  - —Disconnect
- Must have switching capacity and channel capacity to establish connection
- Must have intelligence to work out routing

Public Circuit Switched Network



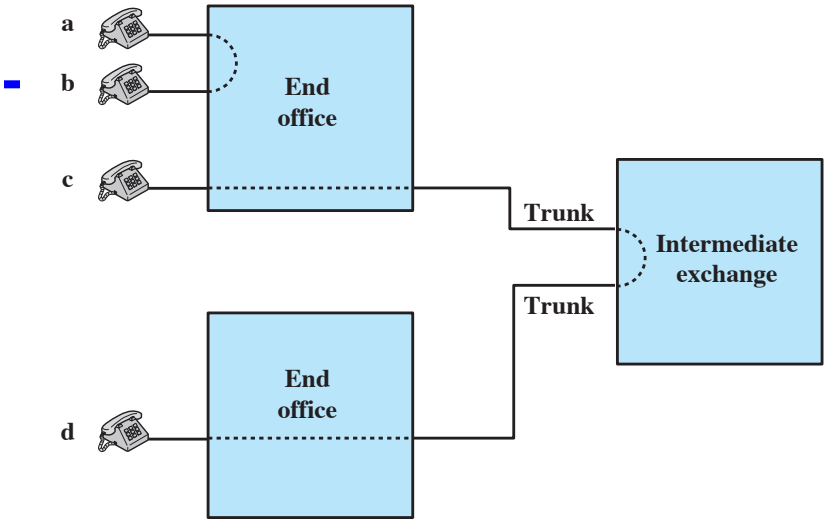


Figure 9.3 Circuit Establishment

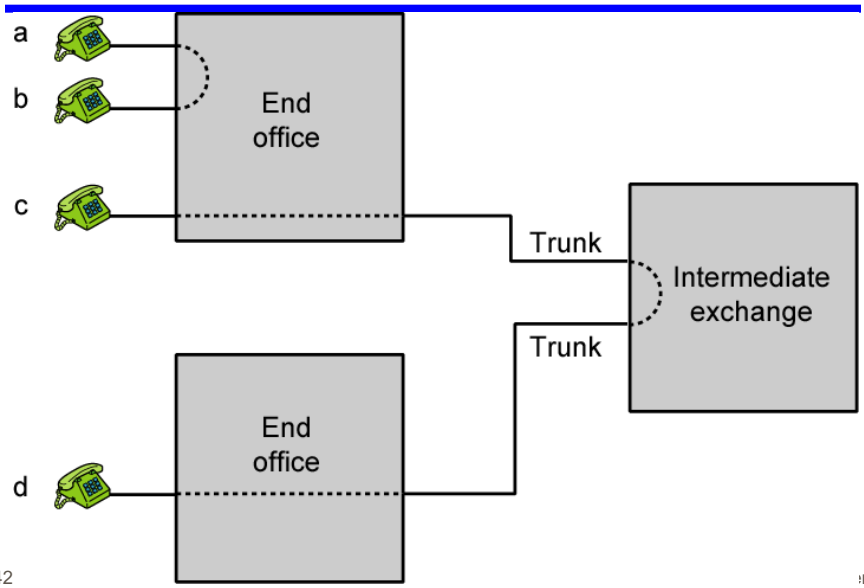
Circuit-Switching Technology

- Driven by applications that handle voice traffic
  - —Key requirement is no transmission delay and no variation in delay
- Efficient for analog transmission of voice signals
- Inefficient for digital transmission
- Transparent
  - —Once a circuit is established it appears as a direct connection; no special logic is needed

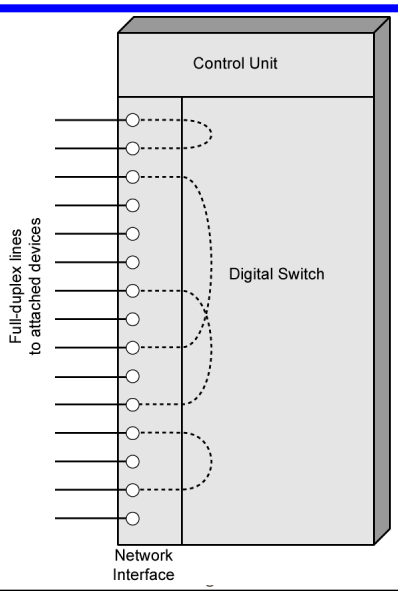
Telecom Components

- Subscriber
  - — Devices attached to network
- Subscriber line
  - — Local Loop
  - — Subscriber loop
  - — Connection to network
  - — Few km up to few tens of km
- Exchange
  - — Switching centers
  - — End office - supports subscribers
- Trunks
  - — Branches between exchanges
  - — Multiplexed

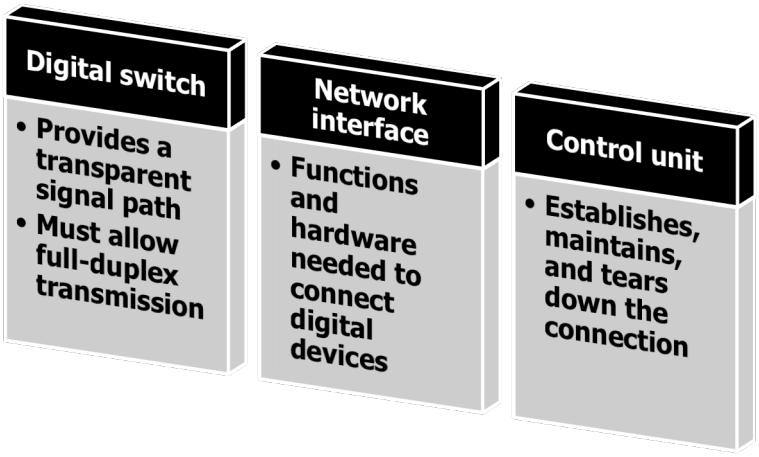
Circuit Establishment



Circuit Switch Elements



Circuit-Switching Concepts



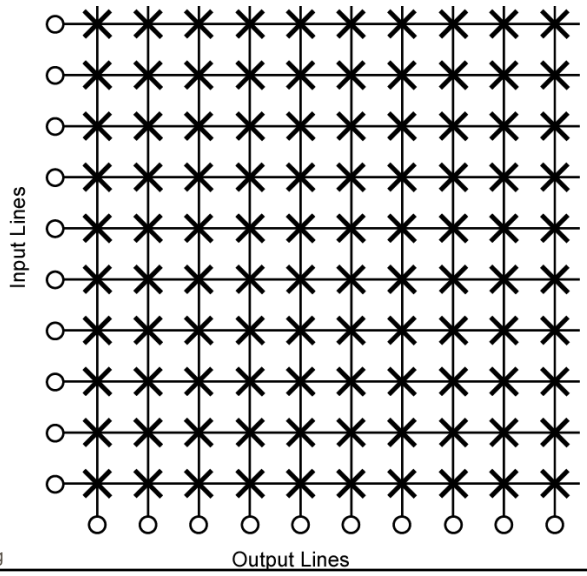
Blocking or Non-blocking

- Blocking
  - —A network is unable to connect stations because all paths are in use
  - —A blocking network allows this
  - —Used on voice systems
    - Short duration calls
- Non-blocking
  - —Permits all stations to connect (in pairs) at once
  - —Used for some data connections

Space Division Switching

- Developed for analog environment
- Separate physical paths
- Crossbar switch
  - —Number of cross-points grows in n^2
  - —Loss of cross-point prevents connection
  - —Inefficient use of cross-points
    - All stations connected, only a few cross-points in use
  - —Non-blocking

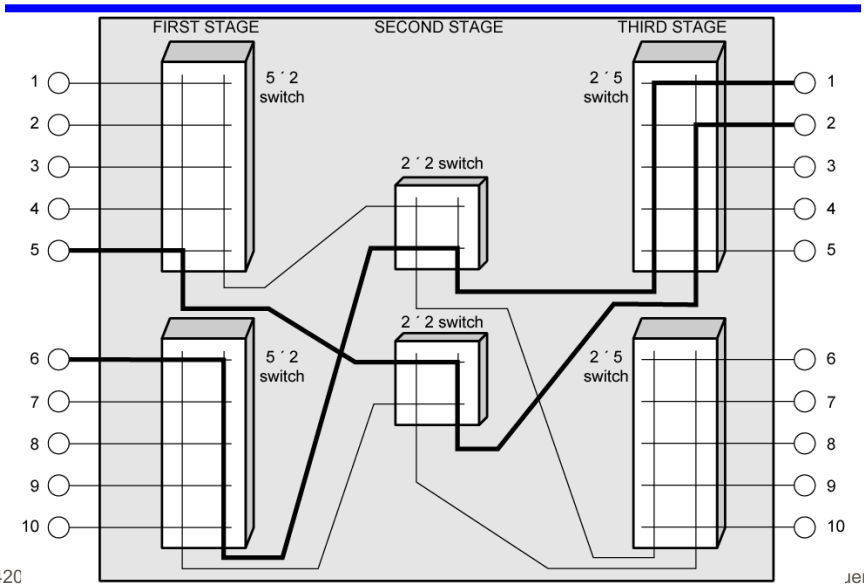
Space Division Switch



Multistage Switch

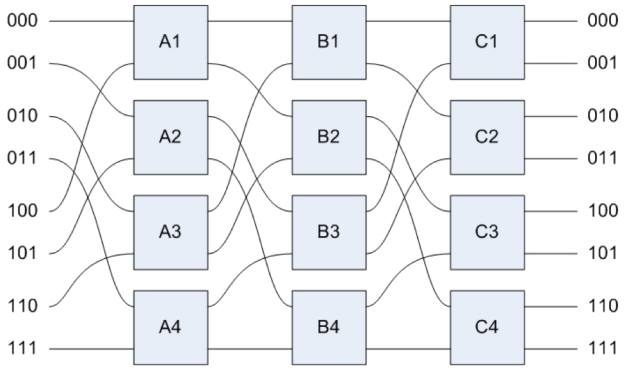
- Reduced number of cross-points
- More than one path through network
  - —Increased reliability
- More complex control
- May be blocking

Three Stage Space Division Switch



Interconnection Networks

- Omega Network

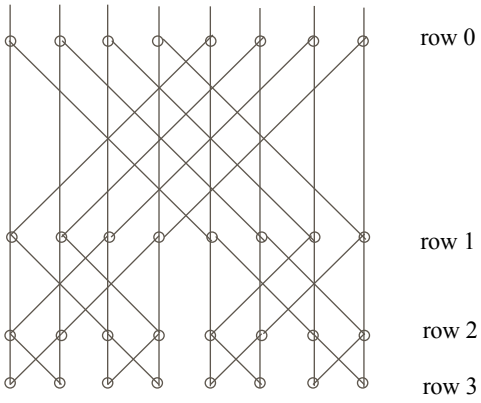


Interconnection Networks

- Butterflies
  - isomorphic to Omega (a composition of shuffle-exchange networks with programmable switches) and SW-Banyan switch
  - closely related to hypercube and shuffle-exchange network
  - number of nodes N = $(k + 1)2^k$
    - this means k + 1 rows (or ranks) consisting of n = 2^k nodes each
  - Let node(*i*,*j*) refer to the *j*-th node in the *i*-th row, where *i* is in [0,k]
  - Then node(i,j) in row i>0 is connected to two nodes in row i-1
    - node(*i*-1,*j*) and node(*i*-1,*m*) where *m* is the integer found by inverting the *i*-th most significant bit in the binary representation of *j*.
  - Note that if node(*i*,*j*) is connected to node(*i*-1,*m*), then node(*i*,*m*) is connected to node(*i*-1,*j*).
  - Benes network is consisting of two butterflies back to back

Interconnection Networks

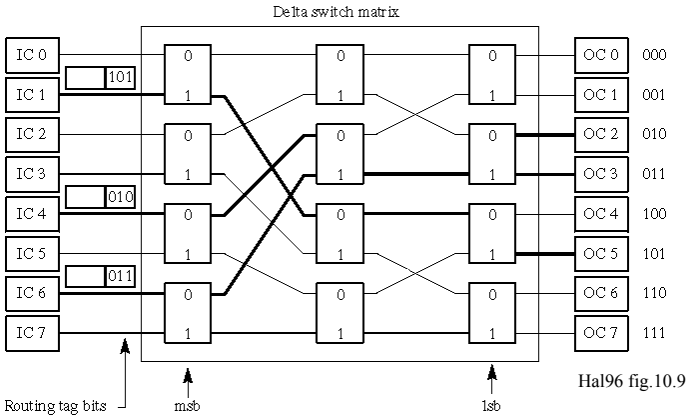
- Butterflies



Interconnection Networks

—Delta Switch Matrix

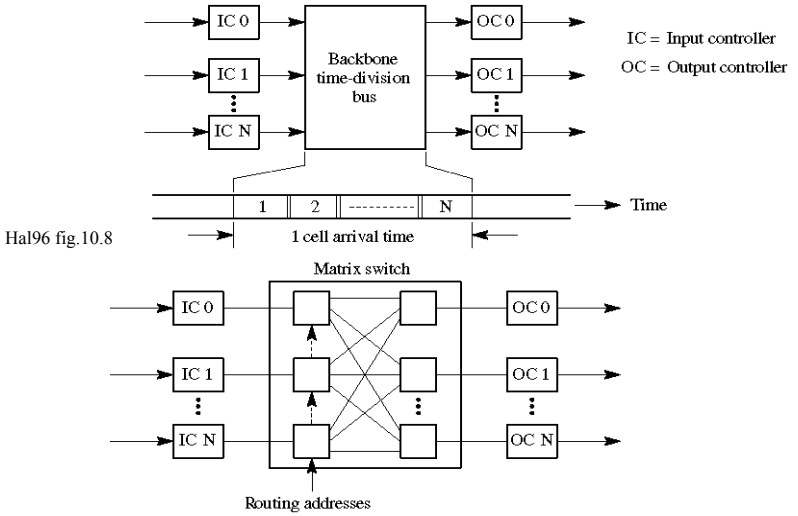
- non-blocking/blocking
- self routing



Hal96 fig.10.9

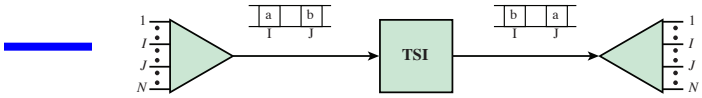
Interconnection Networks

Two extremes

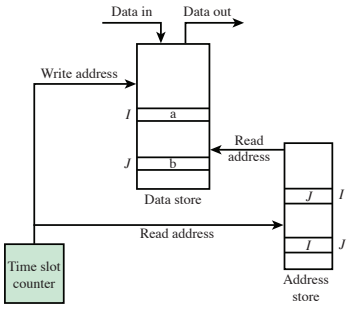


Time Division Switching

- Modern digital systems use intelligent control of space & time division elements
- Use digital time division techniques to set up and maintain virtual circuits
- Partition low speed bit stream into pieces that share higher speed stream
- Individual pieces manipulated by control logic to flow from input to output



(a) TSI Operation



(b) TSI Mechanism

Figure 9.7 Time-Slot Interchange

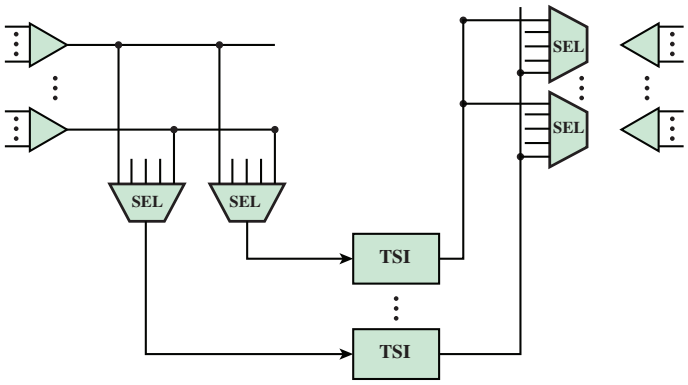
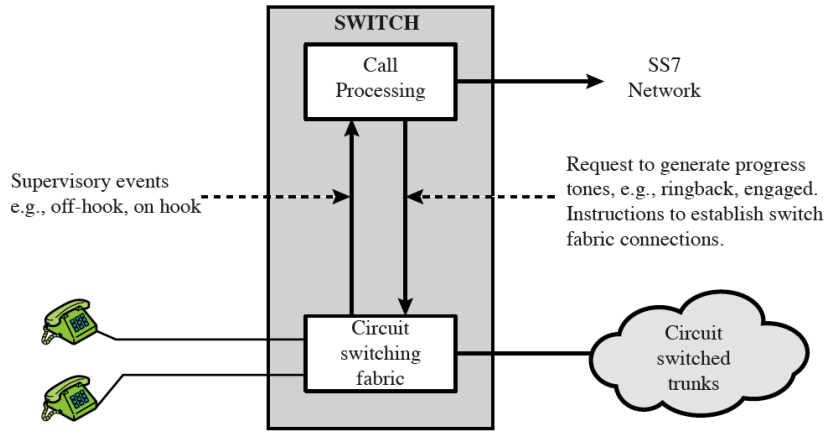


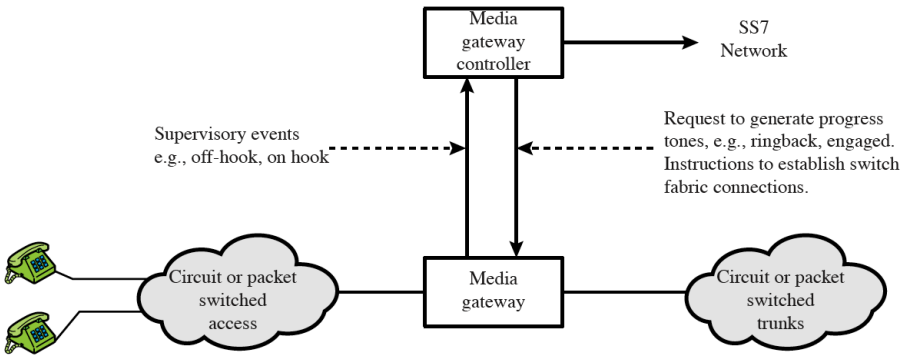
Figure 9.8 A Time-Multiplexed Switch

Traditional Circuit Switching



(a) Traditional circuit switching

Softswitch



(b) Softswitch architecture

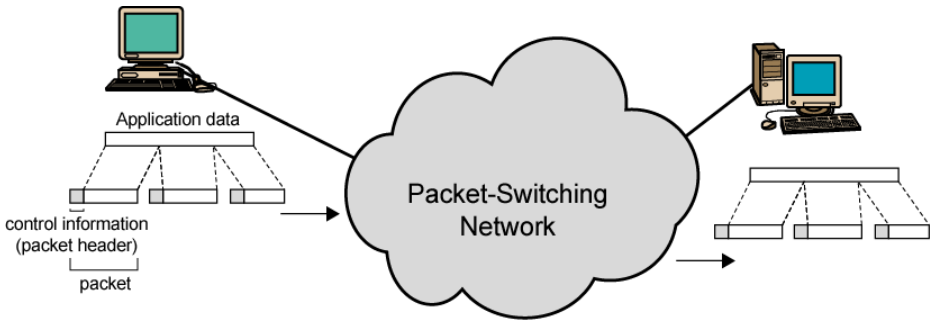
Circuit Switching

- Circuit switching designed for voice
  - —Resources dedicated to a particular call
  - —Much of the time a data connection is idle
  - —Data rate is fixed
    - Both ends must operate at the same rate

Packet Switching:

- Packet switching was designed for data
- Data transmitted in small packets
  - —Typically 1000 octets
  - —Longer messages split into series of packets
  - —Each packet contains a portion of user data plus some control info
- Control info
  - —Routing (addressing) info
- Packets are received, stored briefly (buffered) and past on to the next node
  - —Store and forward

Use of Packets



Advantages

- Line efficiency
  - Single node to node link can be shared by many packets over time
  - Packets queued and transmitted as fast as possible
- Data rate conversion
  - Each station connects to the local node at its own speed
  - Nodes buffer data if required to equalize rates
- Packets are accepted even when network is busy
  - Delivery may slow down
- Priorities can be used

Switching Techniques

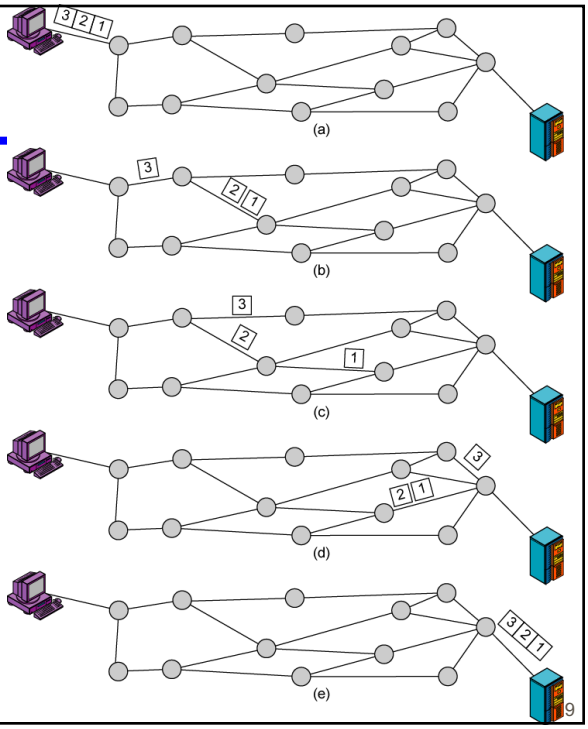
- Station breaks long message into packets
- Packets sent one at a time to the network
- Packets can be handled in two ways:

Datagram	Virtual circuit
• Each packet is treated independently with no reference to previous packets	• A preplanned route is established before any packets are sent

Datagram

- Each packet treated independently
- Packets can take any practical route
- Packets may arrive out of order
- Packets may go missing
- Up to receiver to re-order packets and recover from missing packets

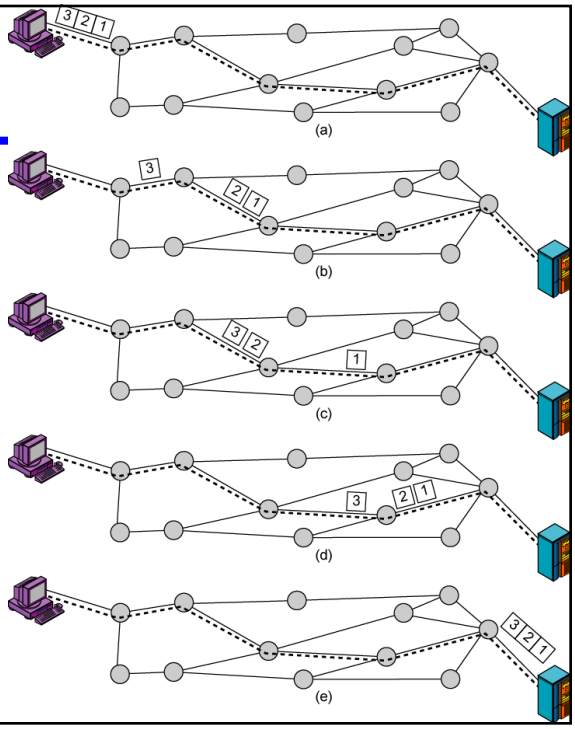
Datagram Diagram



Virtual Circuit

- Preplanned route established before any packets sent
- Call request and call accept packets establish connection (handshake)
- Each packet contains a **virtual circuit identifier** instead of destination address
- No routing decisions required for each packet
- Clear request to drop circuit
- Not a dedicated path

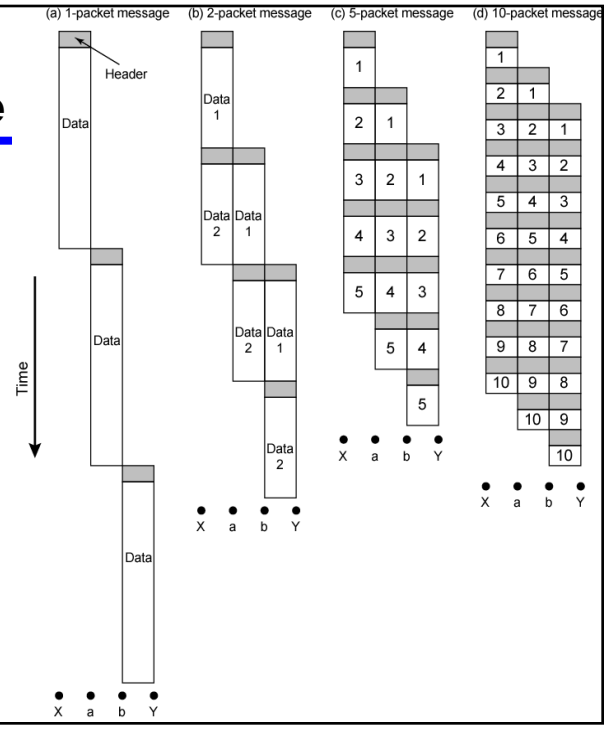
Virtual Circuit Diagram



Virtual Circuits vs. Datagram

- Virtual circuits
  - —Network can provide sequencing and error control
  - —Packets are forwarded more quickly
    - No routing decisions to make
  - —Less reliable
    - Loss of a node looses all circuits through that node
- Datagram
  - —No call setup phase
    - Better if few packets
  - —More flexible
    - Routing can be used to avoid congested parts of the network

Packet Size



Circuit vs Packet Switching

- Performance
  - —Propagation delay
  - —Transmission time
  - —Node delay

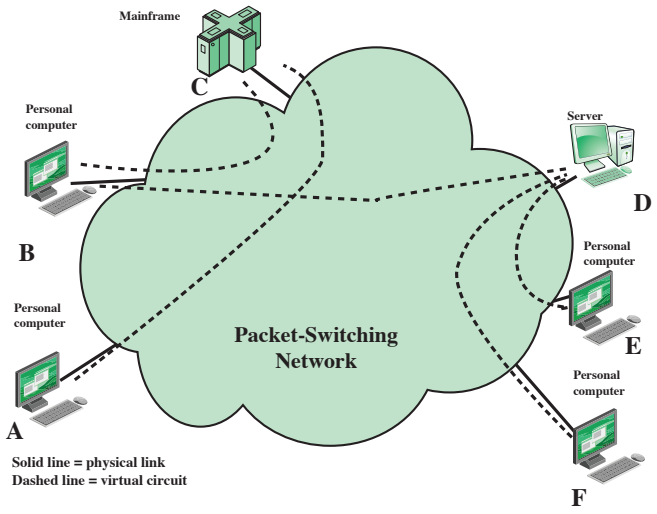


Figure 9.14 The Use of Virtual Circuits

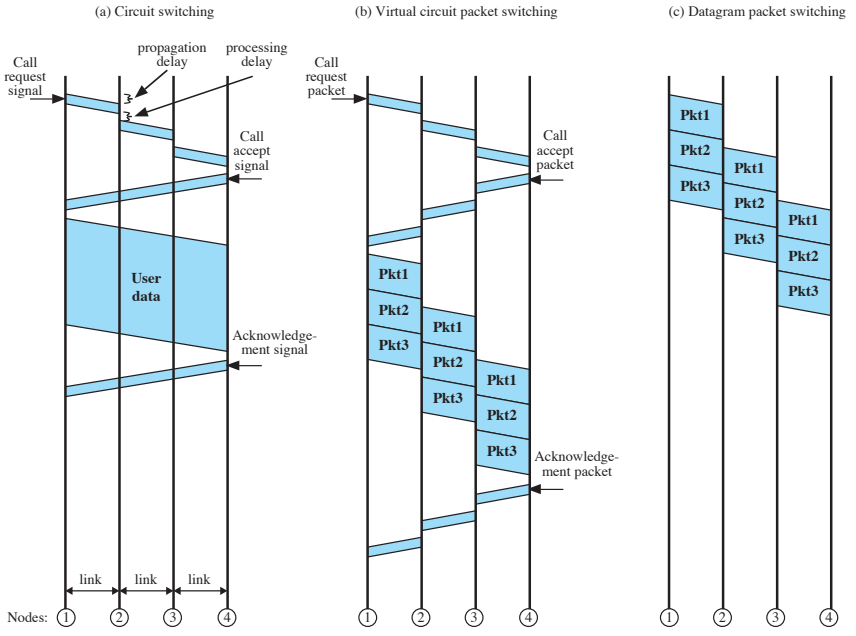


Figure 9.15 Event Timing for Circuit Switching and Packet Switching

Circuit Switching	Datagram Packet Switching	Virtual Circuit Packet Switching
Dedicated transmission path	No dedicated path	No dedicated path
Continuous transmission of data	Transmission of packets	Transmission of packets
Fast enough for interactive	Fast enough for interactive	Fast enough for interactive
Messages are not stored	Packets may be stored until delivered	Packets stored until delivered
The path is established for entire conversation	Route established for each packet	Route established for entire conversation
Call setup delay; negligible transmission delay	Packet transmission delay	Call setup delay; packet transmission delay
Busy signal if called party busy	Sender may be notified if packet not delivered	Sender notified of connection denial
Overload may block call setup; no delay for established calls	Overload increases packet delay	Overload may block call setup; increases packet delay
Electromechanical or computerized switching nodes	Small switching nodes	Small switching nodes
User responsible for message loss protection	Network may be responsible for individual packets	Network may be responsible for packet sequences
Usually no speed or code conversion	Speed and code conversion	Speed and code conversion
Fixed bandwidth	Dynamic use of bandwidth	Dynamic use of bandwidth
No overhead bits after call setup	Overhead bits in each packet	Overhead bits in each packet

Table 9.1

Comparison of Communication Switching Techniques

(Table can be found on page 291 in textbook)

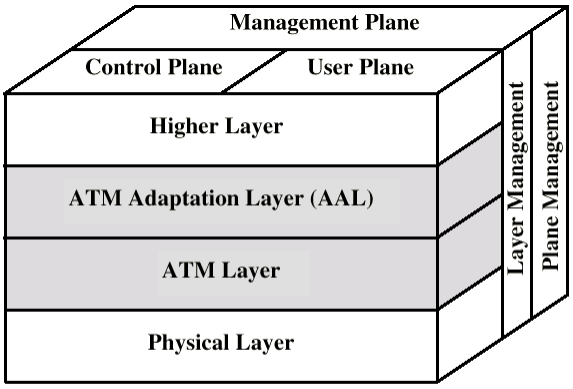
Asynchronous Transfer Mode (ATM)

- A switching and multiplexing technology that employs small, fixed-length packets called cells
- A fixed-size packet ensures function could be carried out efficiently, with little delay variation
- Small cell size supports delay-intolerant interactive voice service with a small packetization delay
- Designed to provide the performance of a circuit-switching network and the flexibility and efficiency of a packet-switching network
- Standardization effort was to provide a powerful set of tools for supporting a rich QoS capability and a powerful traffic management capability

ATM

- Commonly used by telecommunications providers to implement wide area networks
- Used by many DSL implementations
- Used as a backbone network technology in numerous IP networks
- Multiprotocol Label Switching (MPLS) has reduced the role for ATM

Protocol Architecture (diag)



Virtual Channel Connection (VCC)

- Logical connection in ATM
- Analogous to a virtual circuit
- Basic unit of switching in an ATM network
- Set up between two end users through the network, and a variable-rate, full duplex flow of fixed-size cells is exchanged over the connection
- Also used for user-network exchange and network-network exchange

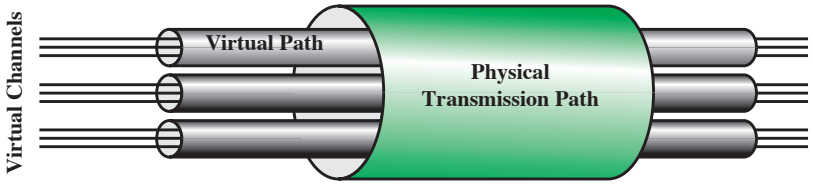
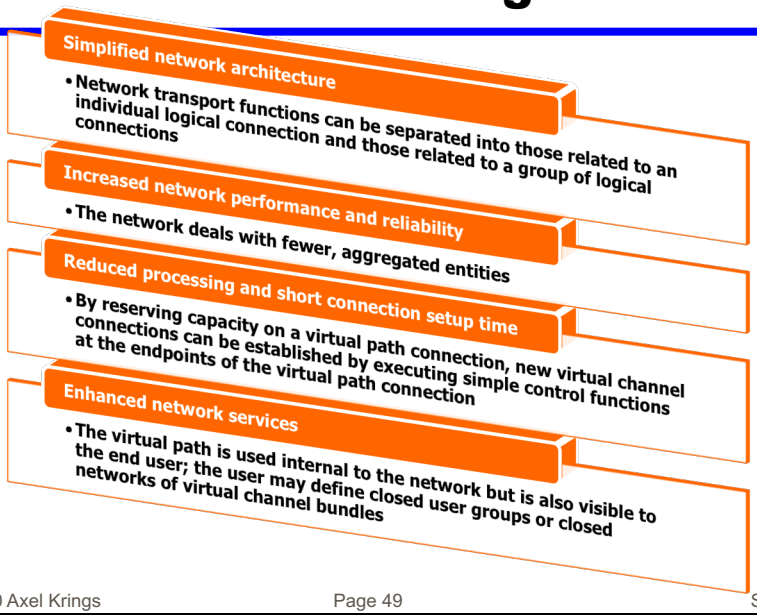


Figure 9.16 ATM Connection Relationships

Virtual Path Advantages



Virtual Channel Characteristics

- ITU-T Recommendation I.150 lists the following characteristics of VCCs:

Quality of service (QoS)
- Specified by parameters such as cell loss ratio and cell delay variation

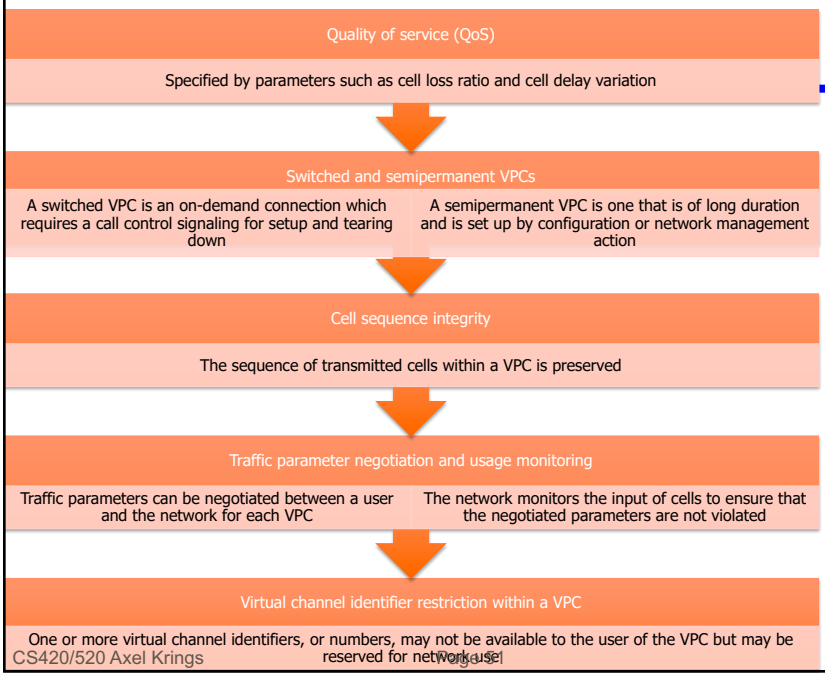
Switched and semipermanent VCCs
- A switched VCC is an on-demand connection which requires a call control signaling for setup and tearing down
- A semipermanent VCC is one that is of long duration and is set up by configuration or network management action

Cell sequence integrity
- The sequence of transmitted cells within a VCC is preserved

Traffic parameter negotiation and usage monitoring
- Traffic parameters can be negotiated between a user and the network for each VCC
- The network monitors the input of cells to ensure that the negotiated parameters are not violated

Virtual Path Characteristics

ITU-T Recommendation I.150 lists the following characteristics of VPCs:



Control Signaling

VCCs

- Semipermanent VCCs may be used for user-to-user exchange
  - No control signaling is required
- If there is no preestablished call control signaling channel, then one must be set up
  - Meta-signaling channel
- The meta-signaling channel can be used to set up a VCC between the user and the network for call control signaling
  - User-to-network signaling virtual channel
- The meta-signaling channel can also be used to set up a user-to-user signaling virtual channel
  - Such a channel must be set up within a preestablished VPC

VPCs

- Can be established on a semipermanent basis by prior agreement
  - No control signaling is required
- VPC establishment/release may be customer controlled
  - The customer uses a signaling VCC to request the VPC from the network
- VPC establishment/release may be network controlled
  - The network establishes a VPC for its own convenience
  - The path may be network-to-network, user-to-network, or user-to-user

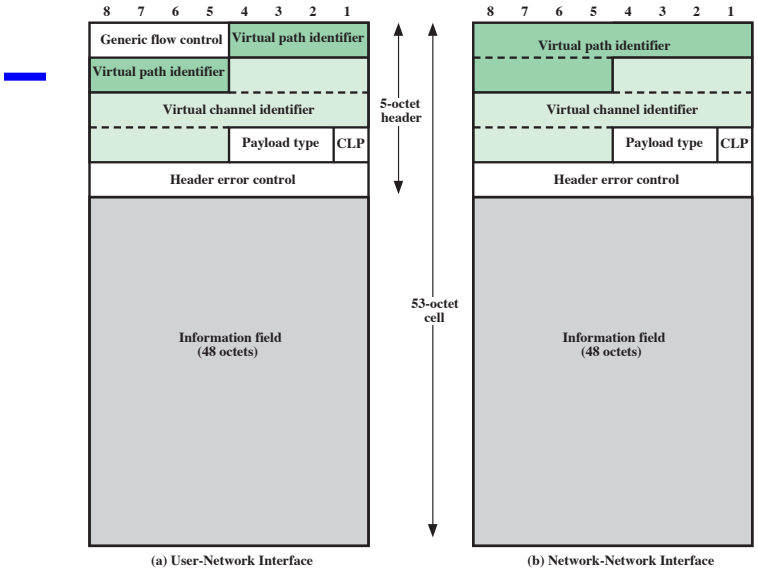


Figure 9.17 ATM Cell Format

Table 9.2

Payload Type (PT) Field Coding

PT Coding	Interpretation		
0 0 0	User data cell,	congestion not experienced,	SDU-type = 0
0 0 1	User data cell,	congestion not experienced,	SDU-type = 1
0 1 0	User data cell,	congestion experienced,	SDU-type = 0
0 1 1	User data cell,	congestion experienced,	SDU-type = 1
1 0 0	OAM segment associated cell		
1 0 1	OAM end-to-end associated cell		
1 1 0	Resource management cell		
1 1 1	Reserved for future function		

SDU = Service Data Unit
OAM = Operations, Administration, and Maintenance

Summary

- Switched communications networks
- Circuit-switching networks
- Circuit-switching concepts
  - —Space division switching
  - —Time-division switching
- Softswitch architecture
- Packet-switching principles
  - —Switching technique
  - —Packet size
  - —External network interface
  - —Comparison of circuit switching and packet switching
- Asynchronous transfer mode
  - —ATM logical connections
  - —ATM cells